NRCS EFH CHAPTER 2 - ESTIMATING RUNOFF

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Definitions

- Surface runoff – the volume of excess water that runs off a drainage area.
- Peak discharge is the peak rate of runoff from a drainage area for a given rainfall.
- EFH-2 Assumption: Rainfall is the primary source of water that runs off the surface of small rural watersheds.

General

- The main factors affecting the volume of rainfall that runs off the surface are the kind of soil and the type of vegetation in the watershed.
- Factors affecting the rate at which water runs off are the watershed topography and shape along with conservation practices on a watershed.

Rainfall

- The peak discharge from a small rural watershed is usually caused by intense rainfall.
- To avoid the use of a different set of rainfall intensities for each drainage area, a set of synthetic rainfall distributions was developed.
- This set maximizes the rainfall intensities by including short duration with those needed for longer duration.

Rainfall *(Continued)*

- Based on the watershed size for which NRCS typically provides assistance, a storm duration of 24 hours was chosen for the synthetic distribution.
- The 24-hour storm while longer than needed to determine peak discharges, is suitable for determining runoff volumes.
- A single storm duration and the associated synthetic rainfall distribution can be used to estimate peak discharges for a wide range of watershed areas.

Rainfall *(Continued)*

- The intensity of rainfall varies significantly during the storm period.
- Four 24-hour storm distributions were developed by SCS (NRCS) from U.S. National Weather Service data as typical design storms. The distributions are associated with climatic regions.
  - Type I
  - Type IA
  - Type II (All of NC except Coastal Plain)
  - Type DMV-Delmarva (Coastal Plain of NC)
  - Type III

Hydrologic Soil Groups

- NRCS Soil Scientists have classified soils into four hydrologic soil groups
  - Group A – Low runoff potential and high infiltration rates even when thoroughly wetted. Mostly sands and gravels that are deep, well drained to excessively drained with a high rate of water transmission (>0.30 in/hr).
  - Group B – Moderate infiltration rates when thoroughly wetted. Mostly moderately deep to deep soils that are moderately well drained to well drained with moderately fine to moderately coarse textures. Moderate rate of water transmission (0.15 to 0.30 in/hr)

Hydrologic Soil Groups *(Continued)*

- Group C – Low infiltration rates when thoroughly wetted. Chiefly consists of soils with a layer that impedes downward movement of water with moderately fine to fine texture. Slow rate of water transmission (0.05 to 0.15 in/hr).
- Group D – High runoff potential with very low infiltration rates when thoroughly wetted. Mostly clay soils with high swell potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. Very low rate of water transmission (0 to 0.05 in/hr).

Factors Affecting Runoff

- Cover type
- Conservation practices or treatment
  - Reduce erosion
  - Maintain an open structure at the soil surface which reduces runoff. The effect diminishes quickly with increases in storm magnitude.
- Hydrologic conditions
  - Affects the volume of runoff more than any other single factor
  - Consider the effects of cover type and treatment on infiltration and runoff
  - Generally estimated from density of plant cover and residue on the ground surface

Topography

- Slopes in a watershed have a major effect on the peak discharge at downstream points.
- As watershed slope increases, velocity increases, T_c decreases, and peak discharge increases.
- An average watershed is fan shaped. If the shape is elongated or more rectangular, the Tc increases and peak discharge decreases.

Potholes and Marshland

- Potholes may trap rain and as a result reduce the amount of runoff.
- If potholes and marshland areas make up 1/3 or less of the total watershed and do not intercept the drainage from the remaining 2/3, they will not contribute much to the peak discharge.
  – These areas may be excluded from the drainage area for estimating peak discharge.
  – If potholes or marshland constitute more than 1/3 of the total drainage or they intercept the drainage, use NEH-4 procedures to estimate peak discharge.

Limitations of EFH-2 Procedures

- The watershed drainage area must be greater than 1.0 acre and less than 2,000 acres.
- NOTE: If the drainage area is outside these limits, another procedure such as TR-55 or TR-20, Project Formulation - Hydrology, should be used to estimate peak discharge.
- The watershed should have only one main stream. If more than one exists, the branches must have nearly equal T_c's.

Limitations of EFH-2 Procedures (Continued)

- The watershed must be hydrologically similar [i.e., able to be represented by a weighted curve number (CN)]. Land use, soils, and cover are distributed uniformly throughout the watershed. The land use must be primarily rural. If urban conditions are present and not uniformly distributed throughout the watershed, or if they represent more than 10 percent of the watershed, then TR-55 or other procedures must be used.

Limitations of EFH-2 Procedures (Continued)

- If the computed T_c is < 0.1 hour, use 0.1 hour. If the computed T_c is > 10 hours, peak discharge should be estimated using the NEH-4 procedures which are automated in the TR-20 computer program.
- When the flow length is < 200 feet or > 26,000 feet, use another procedure such as TR-55 to estimate T_c and peak discharge.
- Runoff and peak discharge from snowmelt or rain on frozen ground cannot be estimated using these procedures. NEH-4 (TR-20) provides a procedure for estimating peak discharge in these conditions.

Limitations of EFH-2 Procedures (Continued)

- If potholes constitute more than one-third of the total drainage area or if they intercept the drainage, use the procedures in NEH-4.
- When the average watershed slope is < 0.5 percent, a different unit hydrograph shape can be used. Contact the State Conservation Engineer for necessary information.
- When the weighted CN is < 40 or > 98, use another procedure to estimate peak discharge.

Limitations of EFH-2 Procedures (Continued)

- When the average watershed slope is > 64 percent or < 0.5 percent, used another procedure such as TR-55 to estimate T_c.
- Accuracy of peak discharge estimated by this method will be reduced if I_a/P ratio used is outside the range given in Exhibits 2-I, 2-II, and 2-III.
  - The limiting I_a/P ratios are to be used. For example: if I_a/P in Exhibit 2-II is < 0.1, use 0.1; and if I_a/P is > 0.5, use 0.5.

Estimating Runoff

- The runoff from a watershed may be expressed as the average depth of water that would cover the entire watershed. The depth is usually expressed in inches.
- The volume of runoff is computed by converting depth over the drainage area of the watershed to volume. The volume is usually expressed in acre-feet.

Runoff Curve Number (CN)

- The SCS runoff equation is:

$$Q = \frac{(P-I_a)^2}{(P-I_a) + S}$$

Where Q = runoff (inches)

P = rainfall (inches)

I_a = initial abstraction (inches)

S = potential maximum retention after runoff begins (inches)

Initial Abstraction (I_a)

- Includes all losses before runoff begins.
  - Water retained in surface depressions
  - Water intercepted by vegetation
  - Water lost to evaporation
  - Infiltration
- Through studies of many small agricultural watersheds, I_a was found to be approximated by:

$$I_a = 0.2S$$

Runoff Curve Number (CN)

- Substituting $I_a = 0.2S$ in the SCS runoff equation:

$$Q = \frac{(P-0.2S)^2}{P + 0.8S}$$

- Since potential maximum retention can range from 0 on a smooth impervious surface to infinity in deep gravel, the S-values were converted to CN's:

$$CN = \frac{1000}{10 + S}$$

Runoff Curve Number (CN)

- Using the previous equation, when S is zero, the CN is 100.
- As S approaches infinity, the CN approaches zero.
- Therefore, CN’s can range from zero to 100
- **But for practical applications, CN values are limited to a range of 40 to 98**

Estimating Runoff (Q)

- When CN and rainfall (P) have been determined for the watershed, determine runoff (Q) by using Figure 2-26 (Page 2-40) or Table 2-2 (Page 2-84).

- COMPLETE EXERCISE BY HAND
  - Determine CN (runoff curve number) using Worksheet 1 (Page 2-90)
  - Determine P (rainfall)
  - Determine Q (runoff)

Time of Concentration (T_c)

- T_c is the time it takes for runoff to travel from the hydraulically most distant point of the watershed to the outlet.
- T_c influences the peak discharge.
  - For the same size watershed, the shorter the T_c, the larger the peak discharge.

Time of Concentration (T_c)

- T_c can be estimated for small rural watersheds using the following empirical relationship:

- $$T_c = \frac{\ell^{0.8}\,[(1000/CN) - 9]^{0.7}}{1140\,Y^{0.5}}$$

Where:

T_c = time of concentration (hours)

ℓ = flow length (feet)

CN = runoff curve number

Y = average watershed slope in percent

Average Watershed Slope (Y)

- The average watershed slope (Y) is the slope of the land and not the watercourse.
  - Average watershed slope is an average of individual land slope measurements.
- Y can be determined using the following relationship:

$$Y = \frac{100CI}{A}$$

Where Y = Avg WS Slope (percent)

C = total contour length (feet)

I = contour interval (feet)

A = drainage area in square feet

Flow Length (ℓ)

Flow length is the longest flow path in the watershed from the watershed divide to the outlet. It is the total path water travels overland and in small channels on the way to the outlet.

EXERCISE: Determining Time of Concentration (T_c)

- Use topo map to determine ℓ and Y.
- Use the nomograph in Figure 2-27 (Page 2-41) to determine T_c by completing the top part of Worksheet 2 on Page 2-91.

EXERCISE:

Estimating Peak Discharge (q_p)

- Use Q, I_a/P, T_c and the nomograph on Page 2-14 to estimate Unit Peak Discharge (q_u) for 1-YR, 2-YR, & 25-YR 24-HR storms using the Type II storm distribution.
- Calculate Peak Discharge

$q_p = q_u \times DA \times Q$

Where:

q_u = unit peak discharge (cfs/ac/in)

DA = drainage area (acres)

Q = runoff (inch)

Complete Worksheet 2

Congratulations! Time to check your work.

Check your hand calculations by entering the data in the EFH-2 Software Program